

# Signal contents of combined monthly gravity field models derived from Swarm GPS data

EGU2018-10773 - Session G4.3 - 13 April 2018

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# Multi-approach gravity field models from Swarm GPS data

- ESA/DISC funded project (9/2017 to 9/2018)
- Provide highest-quality monthly Swarm gravity field models (GFM)
- Combine individual gravity solutions, computed with:
  - different kinematic orbit solutions
  - different inversion approaches
- Monthly combined Swarm gravity field models:
  - from Dec. 2013 to Jun. 2018
  - publicly available by end of September 2018 (usual ESA channels)

# Multi-approach gravity field models from Swarm GPS data

- Other EGU 2018 contributions related to this project:
  - Adrian Jäggi et al.: Assessment of individual and combined gravity field solutions from Swarm GPS data and mitigation of systematic errors.  
EGU2018-8944 - 9 April 2018
  - Norbert Zehentner et al.: Investigations of GNSS-derived baselines for gravity field recovery.  
EGU2018-11920 - 12 April 2018

# Kinematic orbit solutions

- TU Delft: **GPS High precision Orbit determination Software Tool** (GHOST) Helleputte (2004); Vermuth et al. 2010
- AIUB: **Bernese** v5.3 Dach et al., (2015); Jäggi et al. (2007)
- IfG: **Gravity Recovery Object Oriented Programming System** (GROOPS) Zehentner et al. (2016)

# Gravity field estimation approaches

- AIUB: **Celestial Mechanics Approach** (CMA), Beutler et al. (2010)
- ASU: **Decorrelated Acceleration Approach** (DAA), Bezdek et al. (2014); Bezdek et al. (2016)
- IfG: **Short-Arc Approach** (SAA), Mayer-Gürr (2006)
- OSU: **Improved Energy Balance Approach** (IEBA), Shang et al. (2015) (not considered in this presentation)

# Combination of individual gravity field solutions

- Variance Component Estimation (VCE)
- More information presented by Adrian Jäggi on Monday (EGU2018-8944)
- Intermediate step in the project: combination at the level of normal equations (NEQ) is the goal

# Combination Scenarios

- **Mixed:** different Gravity Field Estimation Approaches (GFEAs) using different kinematic orbits (KOs)
- **AIUB KO:** different GFEAs using AIUB kinematic orbits
- **DAA GFEA:** Decorrelated Acceleration Approach with different KOs
- **SAA GFEA:** Short Arc Approach with different KOs

# “Mixed” combination scenario

- time-averaged VCE-derived weights

Gravity Field Est. App.	Kinematic orbit solution		
	AIUB	TU Delft	IfG
Celestial Mech. App.	0.37		
Decorr. Acceleration App.		0.23	
Short Arc A.			0.40



# “AIUB KO” combination scenario

- time-averaged VCE-derived weights

Gravity Field Est. App.	Kinematic orbit solution		
	AIUB	TU Delft	IfG
Celestial Mech. App.	0.28		
Decorr. Acceleration App.	0.21		
Short Arc A.	0.51		

# “DAA GFEA” combination scenario

- time-averaged VCE-derived weights

Gravity Field Est. App.	Kinematic orbit solution		
	AIUB	TU Delft	IfG
Celestial Mech. App.			
Decorr. Acceleration App.	0.40	0.25	0.35
Short Arc A.			

# “SAA GFEA” combination scenario

- time-averaged VCE-derived weights

Gravity Field Est. App.	Kinematic orbit solution		
	AIUB	TU Delft	IfG
Celestial Mech. App.			
Decorr. Acceleration App.			
Short Arc A.	0.41	0.28	0.31

# Gravity field model pre-processing

- Truncation to degree 40
- $C_{20}$  replaced with value from *GRACE Technical Note 07*
- Temporal variations relative to static GGM05G (GRACE and GOCE)
- Gaussian smoothing with 750-km radius (unless noted)
- GRACE GFZ RL05 used as reference (with same pre-processing)
- GRACE solutions interpolated to the mid-month epochs of the Swarm solutions (identical for all scenarios)

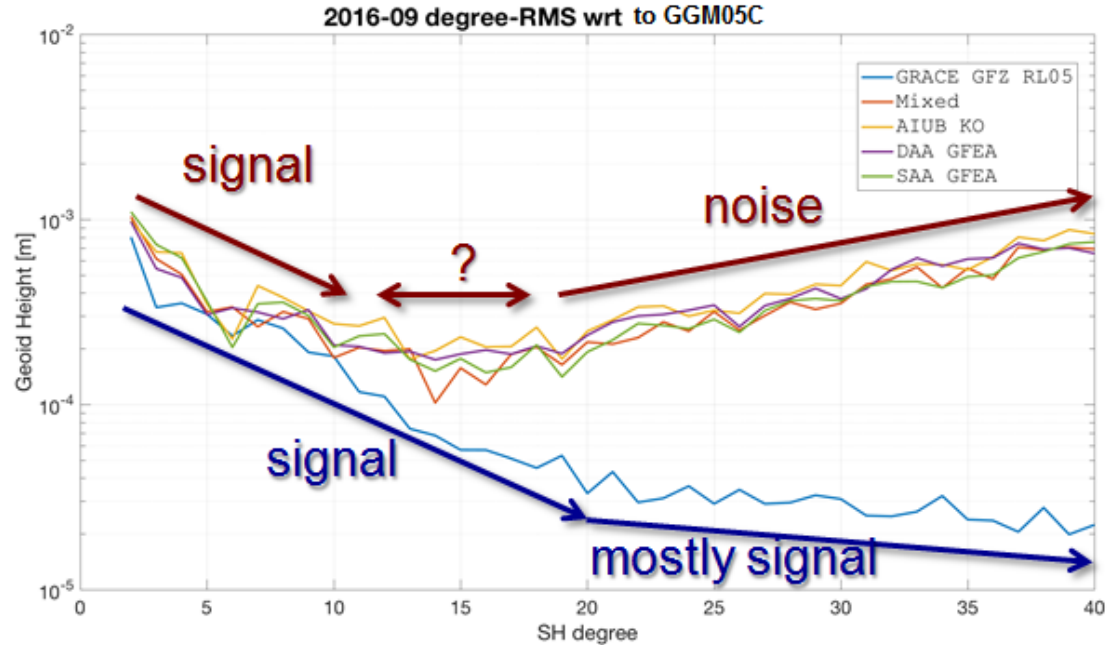
# Typical degree RMS (no smoothing)

## Swarm gravity monthly

- agreement with GRACE up to degrees 10–13
- flattening over degrees 15–20
- noise prevails afterwards
- reason for applying Gaussian smoothing (e.g. 750 km)

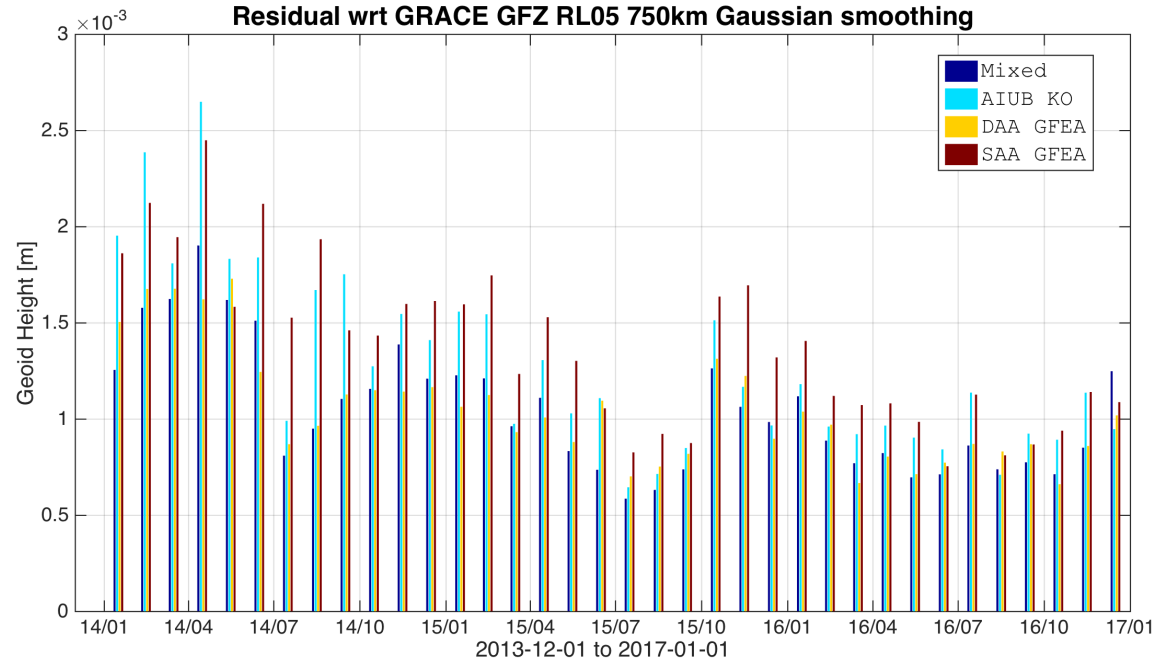
## GRACE gravity monthly

- keeps decreasing in amplitude with higher degrees
- “mostly signal” after degree 15, because mascons start to deviate from SH solutions

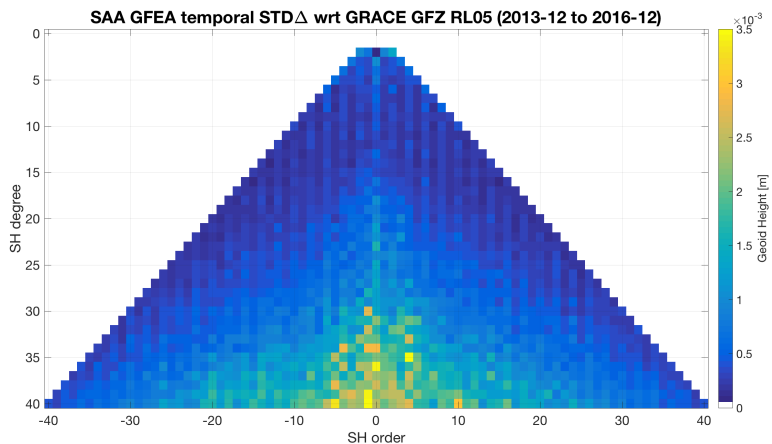
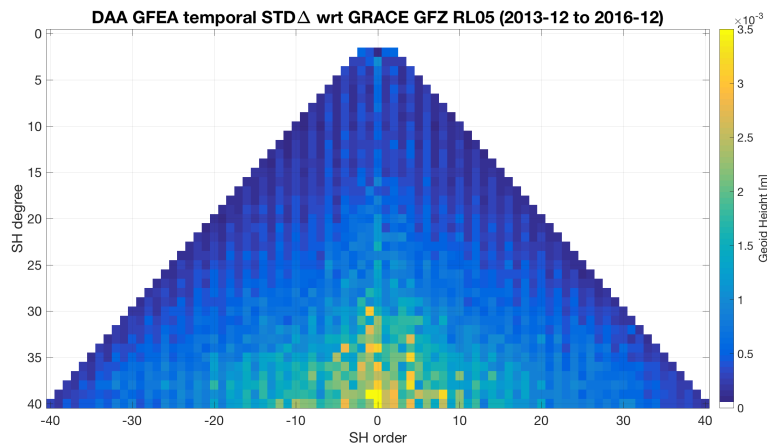
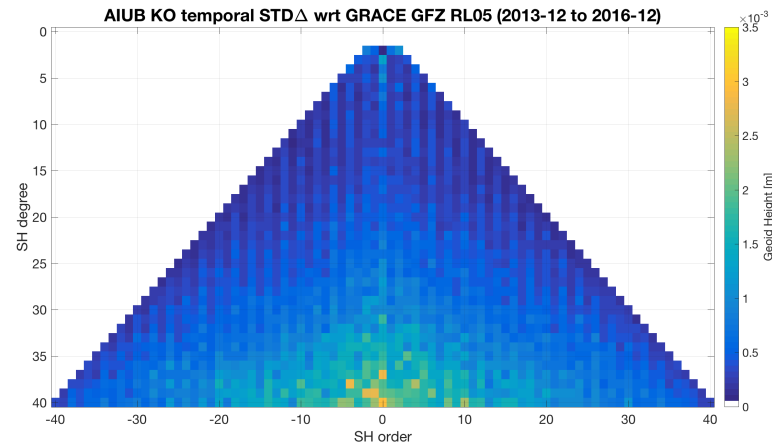
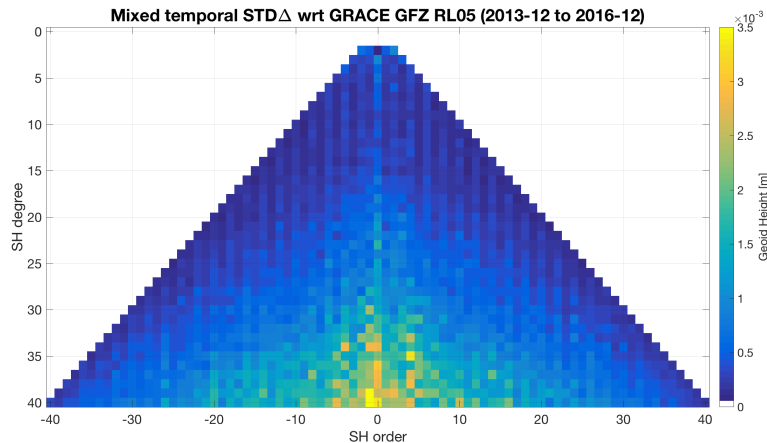


# Spatial agreement with GRACE

- per-solution cumulative degree-RMS of difference between Swarm and GRACE
- same as RMS of the spatial maps of the difference between GRACE and Swarm GFM's
- correlation with intensity of ionospheric disturbances (cf. presentation of A. Jäggi)
- agreement on 1 mm RMS (Gaussian smoothing of 750 km)

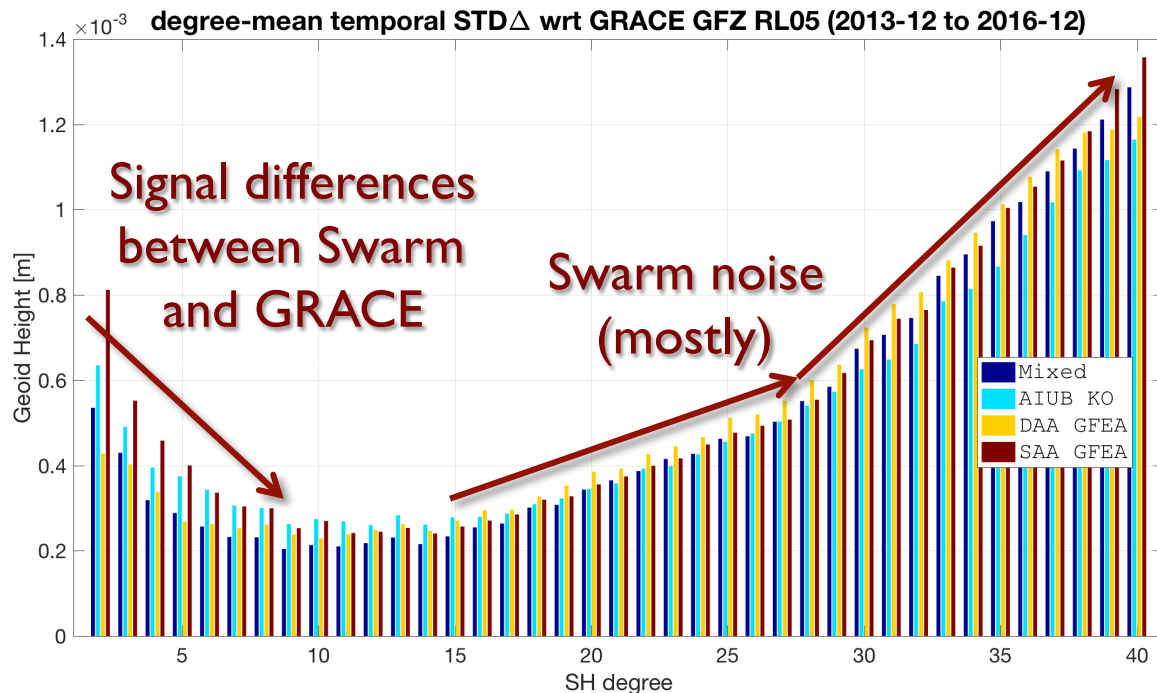


# Temporal agreement with GRACE (no smoothing)



# Temporal agreement with GRACE (no smoothing)

- average of each row in the previous plots
- results for 3 years of data
- Gaussian smoothing is advisable:
  - consider choice of smoothing radius: e.g. 500/660/750 km



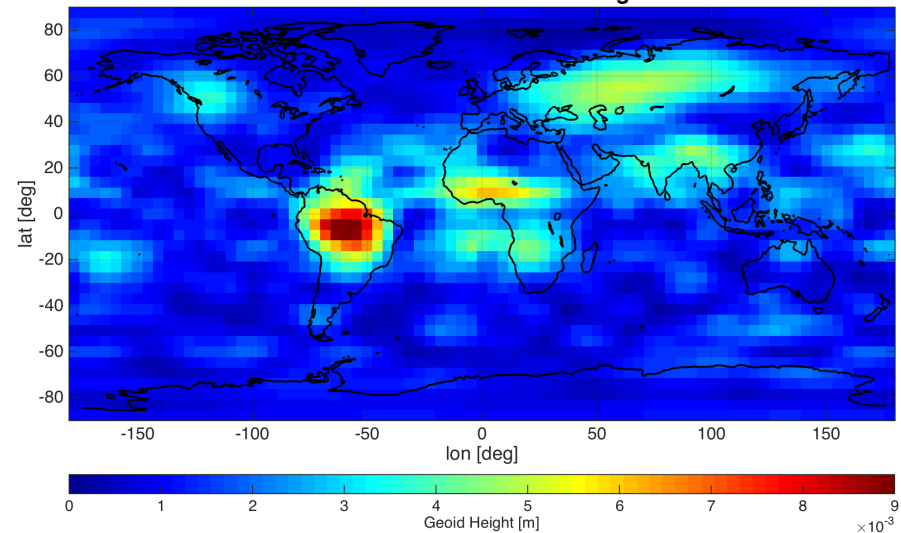


# Parametric decomposition of time-variable Gravity signal in Swarm models

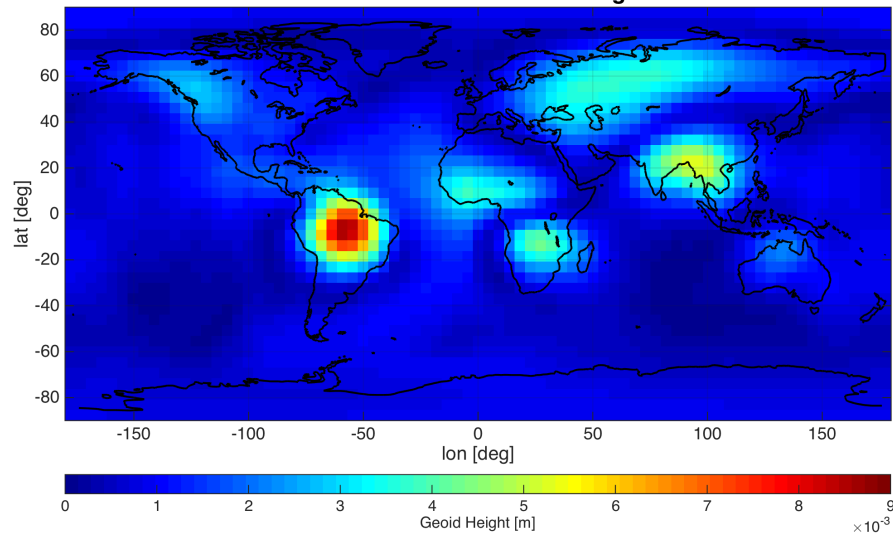
- The Swarm and GRACE time variable signal is represented as:
  - constant
  - trend
  - yearly sinusoidal
- Yearly amplitude maps are the norm of the sine and cosine terms
- GRACE is on right-hand side, the “best” Swarm scenario is on the left

# Yearly amplitude term: “Mixed” scenario

yearly amplitude for Mixed (2013-12 to 2016-12)  
750km Gaussian smoothing



yearly amplitude for grace gfz r105 (2013-12 to 2016-12)  
750km Gaussian smoothing



# Summary and conclusions

- Swarm signal useful below **degree 15**
- Global spatial agreement with GRACE at **1 mm RMS**
  - over periods of low solar activity
  - Gaussian smoothing radius of 750 km
- **Seasonal yearly signal** clearly resolvable by Swarm
  - larger signals over the oceans (consider masking)
- **“Mixed” scenario** in better agreement with GRACE:
  - superior combination is obtained on using **different approaches** to estimating **both KOs and Gravity Field models**

# Stay tuned!

Monthly NEQ-combined Swarm models:

- from Dec. 2013 to Jun. 2018
- publicly available by **end of September 2018**

Research Gate project webpage

- <https://www.researchgate.net/project/Multi-approach-gravity-field-models-from-Swarm-GPS-data>